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0050348E VOL 1SS 13 040000
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Temagami
Pressure Sewer System

Sewage Collection and Treatment
Report SCAT-13

NHA 5540/84

SCAT RESEARCH REPORTS

These RESEARCH REPORTS describe the results of research and development projects in the municipal and domestic wastewater collection, treatment and disposal fields. The projects were identified and developed through the Interdepartmental Committee on Sewage Collection and Treatment (SCAT Research Committee) with the technical assistance of Environment Canada.

Enquiries pertaining to the Wastewater Technology Research Program should be directed to:

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TEMAGAMI PRESSURE SEWER SYSTEM

James F. MacLaren Ltd.

for

Canada Mortgage and Housing Corporation

Report SCAT-13

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This project was carried out under contract for the Policy Development and Research Sector, Canada Mortgage and Housing Corporation, through a grant provided under Part V of the National Housing Act.

This report has been reviewed by the Ontario Ministry of Environment, Canada Mortgage and Housing Corporation and Environment Canada. The views, conclusions and recommendations expressed herein are those of the authors and do not necessarily reflect the views and policies of the government agencies involved. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

Aussi disponible en français.

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Cat. No. En43-51/13E
ISBN 0-662-13453-2

ABSTRACT

This report presents the background to the selection of a shallow buried, low pressure sewer system to service 140 buildings in the community of Temagami in northern Ontario. The results of a two-year monitoring program on the system are also provided.

The pressure sewer system was chosen from several conventional alternatives because of its lower capital cost, reasonable operating costs, proven reliability and ease of construction. Monitoring equipment was installed to record data on energy consumption, and related energy costs were calculated for heat traced pipes and individual grinder pumping units. Pump cycles, ground temperatures, sewage flow, ambient temperature during cold weather, sewer main temperatures and sewer main pressures were also monitored. Results indicated that energy consumption was generally less than anticipated.

Grinder pumps were found to be sensitive to long-term storage prior to installation. Monitoring of system operation was found to be essential to maintain reliability and for early identification of potential problems. In addition, preventative maintenance and preparation for emergencies are important considerations for such shallow buried systems.

The evaluation and monitoring program, carried out by James F. MacLaren Ltd. in consultation with the Ontario Ministry of the Environment, demonstrated on a quantitative basis that a pressure sewer system is suitable for servicing a community located in rocky terrain.

RÉSUMÉ

Ce rapport fait état des diverses considérations qui ont conduit au choix d'un réseau peu profond d'égouts à faible pression pour desservir 140 bâtiments de la localité de Temagami, dans le nord de l'Ontario. Il fait également état des résultats de deux ans de surveillance du réseau.

Ce réseau d'égouts sous pression a été préféré à plusieurs autres à cause des investissements moindres qu'il exigeait, de ses frais d'exploitation raisonnables, de sa fiabilité éprouvée et de sa facilité d'installation. Sa consommation d'énergie a été relevée à l'aide d'un équipement de surveillance spécial et les coûts d'électricité du système de réchauffement des conduites (traçage électrique) et de chaque pompe à broyeur ont été calculés. On a également contrôlé les cycles de pompage, la température du sol, le débit des égouts, la température ambiante par temps froid, ainsi que la température et la pression dans le collecteur principal. Les résultats montrent que la consommation d'énergie est généralement moindre que prévu.

Il est apparu que les pompes à broyeur étaient sensibles au stockage prolongé avant leur installation et que le contrôle du fonctionnement du réseau était essentiel pour en assurer la fiabilité et repérer rapidement tout problème éventuel. L'entretien préventif et la préparation pour les cas d'urgence sont importants pour ce type de réseau.

Le programme d'évaluation et de contrôle, réalisé par James F. MacLaren Ltd., en consultation avec le ministère de l'Environnement de l'Ontario, a démontré, chiffres à l'appui, qu'un réseau sous pression convient à une localité située en terrain rocheux.

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SUMMARY

The report presents background information on the sanitary system evaluation process leading to the selection of a low pressure sewer system for Temagami, Ontario. This report also provides the results of a two-year monitoring program which reviewed and documented the performance of the Temagami sewer system from October 1979 through September 1981.

System Selection

The system, owned and operated by the Ontario Ministry of Environment on behalf of the Town of Temagami, was selected based on a comparison of several engineering, environmental and cost criteria. It was found to be a better alternative than gravity sewers, individual systems or holding tanks and haulage.

Capital Costs

Capital costs were approximately half of those for a conventional gravity sewer at this location.

System Operation

Since commissioning in March 1979, the sewer system has operated continuously. Operating difficulties were generally minor, and were readily handled by the local system operator.

Operating Costs

Costs for public and private portions of the system were generally as estimated. Higher, but not excessive, costs for the public sewer heat tracing were due to the unanticipated Ontario Hydro rate structure. During discussions with Ontario Hydro representatives, it was recommended that the Town of Temagami request that sewer energy costs be billed as a single charge rather than as individual invoices for each of the 17 power points, thus avoiding excessive demand charges. This suggestion was relayed to the Temagami Works Department on 13 November 1981. A comparison of actual costs vs. estimated costs is presented in Section 6.

Pressure Sewer System Hydraulic Profile

Pressures recorded indicated that the actual average hydraulic gradient was very close to the design gradient, and therefore acceptable. These findings confirmed a number of assumptions made during the design phase.

Sewage Temperatures

Temperatures in the sewer mains were found to be at least 3 to 5°C above freezing during the winter months, providing reasonable reserve heat for emergency conditions such as extended power outage.

Soil Temperatures

Temperatures in the vicinity of the shallow buried pipe (0.5 - 1 m deep) were found to be between 0 and -2°C, indicating minimal heat losses from the insulated pipe.

Sewage Flows

At the conclusion of the monitoring period, with most buildings on-line, daily sewage flow was only 535 L per building per day. As 25% of users are commercial or government facilities, this unit sewage generation rate is considered quite low. It also reflects no infiltration.

Repair and Maintenance

Pre-servicing of stored grinder pumps was found to be particularly important to ensure reliable operation. A program of operating each pump and confirming pumping capability, power draw and proper operation of controls before installation was initiated in March of 1980. Although some repair and upgrading of the system was required after the initial operating period through 1980, reliable operation of the sewer system was not affected.

Benefits of the Monitoring Program

The 30-month monitoring program provided base data on system energy consumption, performance operability and design (temperature and pressure profiles, etc.), together with grinder pump performance, operation and maintenance requirements, and related operation and maintenance costs. This data will be useful in assessing the original design parameters, and will provide a solid basis for modifying and improving design and operation of future installations.

Also, information gathered indicated that while systematic monitoring and preventative maintenance of low pressure sewer systems are very important, the technical capability required by operation and maintenance personnel is not excessive. The Temagami installation is not considered a high technology system.

Monitoring Program Conclusions

The 30-month monitoring program indicated that this type of pressure sewer system, having operated continuously under actual conditions, is very reliable. The success is attributed to appropriate system design; physical suitability of piping, insulation and equipment elements; and proper operation and maintenance by the system operator.

Strict supervision during the construction stage of any future system should be emphasized to ensure reliable operation of sensitive system components such as heat tracing cables. Preventative maintenance and preparation for emergencies are also vital considerations for such shallow buried systems.

The monitoring program demonstrated that low cost shallow buried pressure sewer systems are suitable for servicing communities located on difficult terrain, namely rocky, hilly, soggy and low lying.

1 INTRODUCTION

1.1 General

Until 1978, Temagami, Ontario, had very inadequate sanitary facilities. These are described in Section 1.2. A pressure sewer was constructed in the town in 1977-78 by the Ontario Ministry of Environment and has been in continuous operation since 1978. The system was based on proven technology but was considered to be a prototype in its application to a municipal environment with extreme climatic conditions.

As the system had potential for national scope and could be less expensive than conventional alternatives in similar applications, the Canada Mortgage and Housing Corporation decided to fund a monitoring study under its Sewage Collection and Treatment Program (SCAT). The Corporation also wanted to have a system that could be visited more easily for demonstration purposes than the one that was then in place and operating at Rose Blanche, Newfoundland.

On November 22, 1979, the Corporation retained the services of James F. MacLaren Ltd. to carry out a two-year monitoring program under the direction of the Ministry of the Environment of Ontario. The primary objectives of the program were to:

- evaluate the design principles and criteria,
- evaluate the operation of the system with particular attention to its reliability,
- assess the repair and maintenance requirements,
- collect and analyse data on operation and maintenance costs, and
- make recommendations on future system design and construction.

This report presents a summary of the selection process and the results of the monitoring program and makes recommendations for the future design, operation and maintenance of pressure sewer systems.

1.2 Background

The town of Temagami is approximately 100 km north of North Bay on Highway 11 at the northeast arm of Lake Temagami. Temagami is the centre of transportation for the Lake Temagami area, having railway and highway arteries, boat lines and air service.

Before construction of the sewer system the topography of the area restricted Temagami's potential for expansion. Houses were built indiscriminantly on a series of hilly rock outcrops and in valleys. Surface rock is visible on approximately 60% of the

built-up area; 30% has overburden cover to an average depth of about 600 mm, and the remainder has up to 3 m of overburden. The quality of housing was poor and the settlement lacked a local street system. The only sewerage consisted of a few short sections of storm sewers.

The municipality has a commercial area along Highway 11 comprising service stations, restaurants, souvenir shops, a hardware store and a barber shop. Commercial buildings had to rely on wastewater holding tanks and expensive private haulage. New commercial construction was effectively halted by the lack of a reasonably priced wastewater collection and treatment system. It was recognized that the construction of conventional gravity sewers would be prohibitively expensive in the Temagami topography. It was also recognized that soil conditions within the village did not permit the installation of adequate septic tank and tile bed systems. The effluent from many septic tanks had already found its way into drainage ditches and culverts and eventually into Lake Temagami. High coliform counts near the village confirmed the seepage of septic tank effluent into the lake. Considerable contamination of well water supplies was also occurring.

However, the majority of people within Temagami were determined to remain despite the unsanitary conditions surrounding their homes. In 1974, the Ministry of the Environment of Ontario commissioned an engineering study by Proctor and Redfern Ltd. to investigate all possible alternatives for servicing Temagami. Results of the study are included in the following sections.

2 SELECTION OF A WASTEWATER COLLECTION AND TREATMENT SYSTEM FOR TEMAGAMI

2.1 The Alternatives

Four basic wastewater collection and treatment systems were considered in detail by the Ministry of the Environment. The 1974 engineering study referred to in Section 1.2 investigated and compared the following three options.

- Conventional sewers discharging to a single wastewater treatment plant.
- Collection of wastewater in individual holding tanks with trucking to a treatment facility.
- Individual home package wastewater treatment plants discharging to filter beds or alternatively, after chlorination, to the storm ditch system.

The Ministry and James F. MacLaren Ltd. subsequently considered in detail the fourth option of pressure sewers discharging to a single treatment facility. The Ministry concluded that all four alternatives were technically feasible. In order to make a final selection, each system was reviewed using the following criteria:

- capital costs,
- homeowner costs,
- environmental considerations,
- development stimulus,
- potable water provision,
- general acceptability by residents,
- aesthetics, and
- engineering considerations.

2.1.1 Conventional Sewers and Wastewater Treatment Plant. This system had the highest capital cost but the lowest homeowner costs. It scored highly on all criteria and seemed to be particularly attractive for its potential as a development stimulus. It was also considered the simplest and as providing the most consistent environmental protection. Its major constraint was its very high capital cost, estimated to be approximately twice the cost of a pressure sewer system.

2.1.2 Holding Tanks and Trucking. Holding tank and trucking systems are used extensively in small northern communities. Several factors were against such a system for Temagami. The optimal residential tank size would be 20 000 litres and in most

locations the tanks would have to be set above ground because of the level of the bedrock. They were, therefore, considered to be aesthetically unacceptable. Secondly, such a system was considered a possible deterrent to municipal development. There was the potential for odour problems either at the tank location or the effluent disposal location, a lagoon adjacent to a neighboring municipality. Finally, both the trucks and holding tanks had a limited life span. The capital cost of the system was comparable with the other non-gravity sewer alternatives.

2.1.3 Individual Home Package Wastewater Treatment Plants. The analysis of individual home package wastewater treatment plants was based on the use of a proprietary aerobic treatment system. This system had proven its reliability and high performance throughout Ontario for several years. The system and its associated disposal bed could be designed for a wide variety of site conditions. However, in Temagami, 25 locations were found to be unsuitable. These locations would have to be served by holding tanks and this would not have been cost effective.

2.1.4 Low Pressure Sewer Systems. The capital cost of the low pressure sewer system was comparable with the other non-gravity sewer alternatives. The operating costs were estimated to be significantly lower. The advantage of the system was that it provided servicing to all the present and future buildings in Temagami at a reasonable capital cost and with minimal above ground components. Its impact on development potential for Temagami was seen as positive. The system had proven reliability in applications elsewhere in North America. The main area of uncertainty was its performance under the cold weather conditions of Temagami, and the performance of the individual grinder pumping units.

2.2 Final Selection

The shallow buried low pressure sewer system was selected as the best alternative. It was significantly less costly than gravity sewers and pumping stations and compared favourably with other alternatives under all other criteria. The technology was relatively simple and all components for the system could be delivered quickly through Canadian suppliers.

Du Pont Canada, the manufacturer of the pipes and fittings indicated its intention to provide considerable technical support for the design, construction and operation of this prototype application of its equipment. It was recognized, however, that the operation and maintenance of the system would have to be closely monitored for several years to identify and correct any unforeseen problems.

Other advantages of a shallow buried pressure sewer system for Temagami were:

- The pipe was pre-insulated and heat traced, and therefore required only 450-600 mm of earth cover.
- The piping could be laid out to follow the irregular topography and take advantage of existing soil cover. This, of course, would necessitate obtaining easements from private property owners.
- The system could be constructed rapidly and with a minimum of disturbance to the community.

3 THE TEMAGAMI PRESSURE SEWER SYSTEM

3.1 Description of Sewer System

Construction of the Temagami pressure sewer system began on August 1977 and was completed in August 1978. An evaluation of design and construction difficulties is presented in Section 5.1. The system was to serve 140 existing buildings and has a capacity for handling wastewater from up to 190 buildings. The distribution of buildings connected to the sewer system was as follows:

-	residential	106
-	commercial and retail stores	16
-	restaurants	2
-	hotels	1
-	service stations	4
-	government (municipal, provincial)	11
Total		140

An individual, electrically operated, sewage grinder pump is installed at each building in the basement or in a chamber outside the building. The pump operates automatically with respect to the level in an integral 225-litre fibreglass holding tank. This tank is connected to the main public sewer pipeline by a 37-mm diameter branch line. Branch lines are insulated and electrically heat traced for cold weather protection. At buildings where high volumes of effluent are generated, duplex pumps and/or larger capacity holding tanks are provided.

Sewer mains (50, 75 and 100 mm diameter) convey wastes under pressure to a waste stabilization pond for treatment and discharge to Snake Island Lake. All sewer mains are insulated and heat traced. Twenty main line thermostats control the sewage temperature. These thermostats are located in separate thermostat cabinets on above ground stands adjacent to valve chambers. Each heat trace cable is separately metered.

The thermostat for building service lines is normally located within the building but the sensing bulb itself is attached to the pipe wall and insulated, about 1.2 metres away from the building. It is connected to the thermostat by a gas filled capillary tube. Care must be taken not to damage the tube and allow the gas to escape.

Main line and branch valves are provided throughout the system for sequential start up of the sewer mains in below freezing weather, air purging and draining of the

mains, and backflushing if necessary. Probe points are provided for temperature and pressure monitoring along the mains.

The major elements of the system are:

- 37 mm piping 3800 metres
- 50 mm piping 2200 metres
- 75 mm piping 1165 metres
- 100 mm piping 980 metres
- Valve chambers 29
- Grinder pump manholes 56

System elements were supplied by the following:

- Polyethylene Pipe Du Pont of Canada Ltd.
- Pipe Insulation Shaw Pipe Protection Ltd.
- Heat Trace Cable Thermon Canada Ltd.
- Grinder Pump Units Environment/One Ltd./ITT Grinnell

The major material specifications are:

Pipe: High density PE pipe, Type 3506, Series 100 - CGSB specification 41-GP-25M.
Insulation: Polyurethane - rigid foam - ASTM specification D1622 - Shaw Insul-8.
Outer Jacket: 45-mil high density polyethylene - Du Pont specifications.
Tracer Cable: Thermon Econotrace constant wattage cable (6.5 to 13 watts/metre depending on pipe size).
Tracer Cable Control: Control thermostat with setting of 5°C. High temperature protection cut off thermostat set at 27°C.

3.2 Operation

3.2.1 Pressure Sewer System. The Temagami system is a shallow-buried low-pressure sewer system with a nominal capacity of 267 m^3/d. Figure 1 presents the schematic of the system. A pressure sewer system is structured like a Christmas tree with branches progressively building up from bottom to top. This design is necessary to maintain a maximum velocity range of 0.45 to 2 m/s to scour out system high points at least once per day. The maximum velocity is related to the number of grinder pumps operating simultaneously. In the Temagami system, 10 pumps could be expected to be operating at the same time, and at 42 L/min each, the maximum velocity in a 100-mm diameter pipe would be 0.97 m/s.

The pressure sewer profile and hydraulic gradient presented in Figure 1 show that the system is designed for the combined worst case of maximum static lift and maximum friction run. The actual hydraulic gradient of the system is very close to the design from the lagoon back to valve chamber no. 13. From valve chamber 13 back to the top of the system at the Temagami Electric Building the actual hydraulic gradient is 9 m lower. Ideally, the grinder pumps should have sufficient power to enable the sewage flow to reach the treatment plant without intermediate pumping in the system. This has been accomplished at Temagami.

In case of no-flow in the system during winter and with heat tracing "off", the branches would freeze in four to six hours, and the mains in five to 18 hours. Actual times are considerably longer with snow cover and pipes filled with warm sewage. Connections are provided to blow out the pipeline with compressed air, should this ever be required during an extended outage. Flushing, draining and cleanout connections are also provided. A typical thaw time for frozen piping is five hours for branches, and five to 21 hours for mains. Warm sewage, once it starts flowing, will hasten the thawing.

The grinder pump holding tanks provide a storage capacity of approximately seven hours which should be adequate for repair of a branch main. Corporation stops on building connections permit the external isolation of a building.

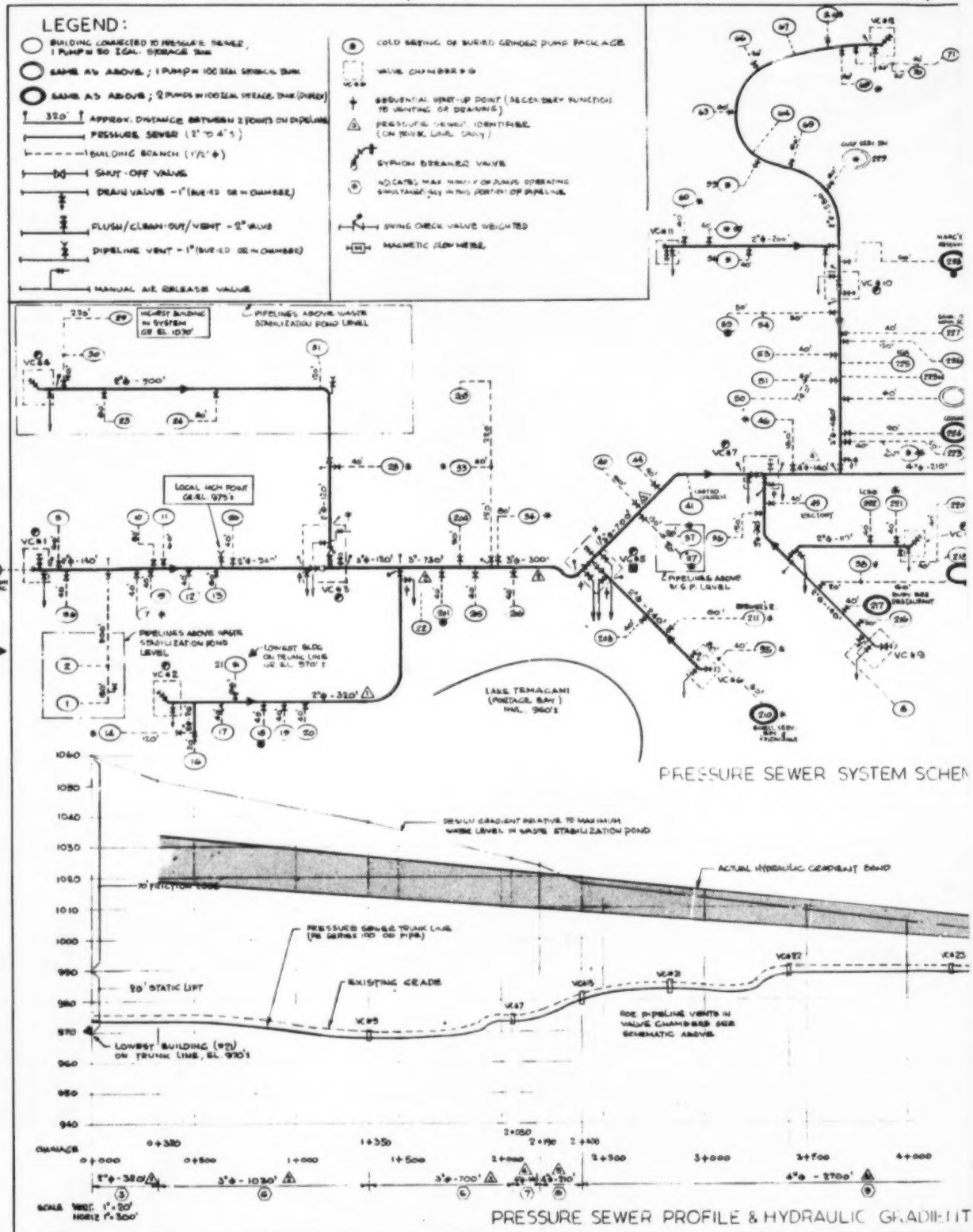
The heat tracing cables are automatically activated by control thermostats to maintain temperature at 4 - 9°C. Service line heat tracers draw 6.5 watts per metre. Heat tracers on all other lines draw 13 watts per metre.

3.2.2 Grinder Pump Units. The grinder pump units are situated in or near each building. The units are made up of the following parts:

i) Fiberglass Holding Tank - Figure 2 shows a typical residential unit with a 225-litre holding tank. Larger tanks are used for commercial operations.

ii) Grinder Pump Core - Sealed within the holding tank is the grinder pump core. This unit, shown in Figure 3, contains the entire working part of the unit; grinder, pump and motor. Should a problem develop, the entire core can be readily removed for repair and quickly replaced with a new core to keep the system operating.

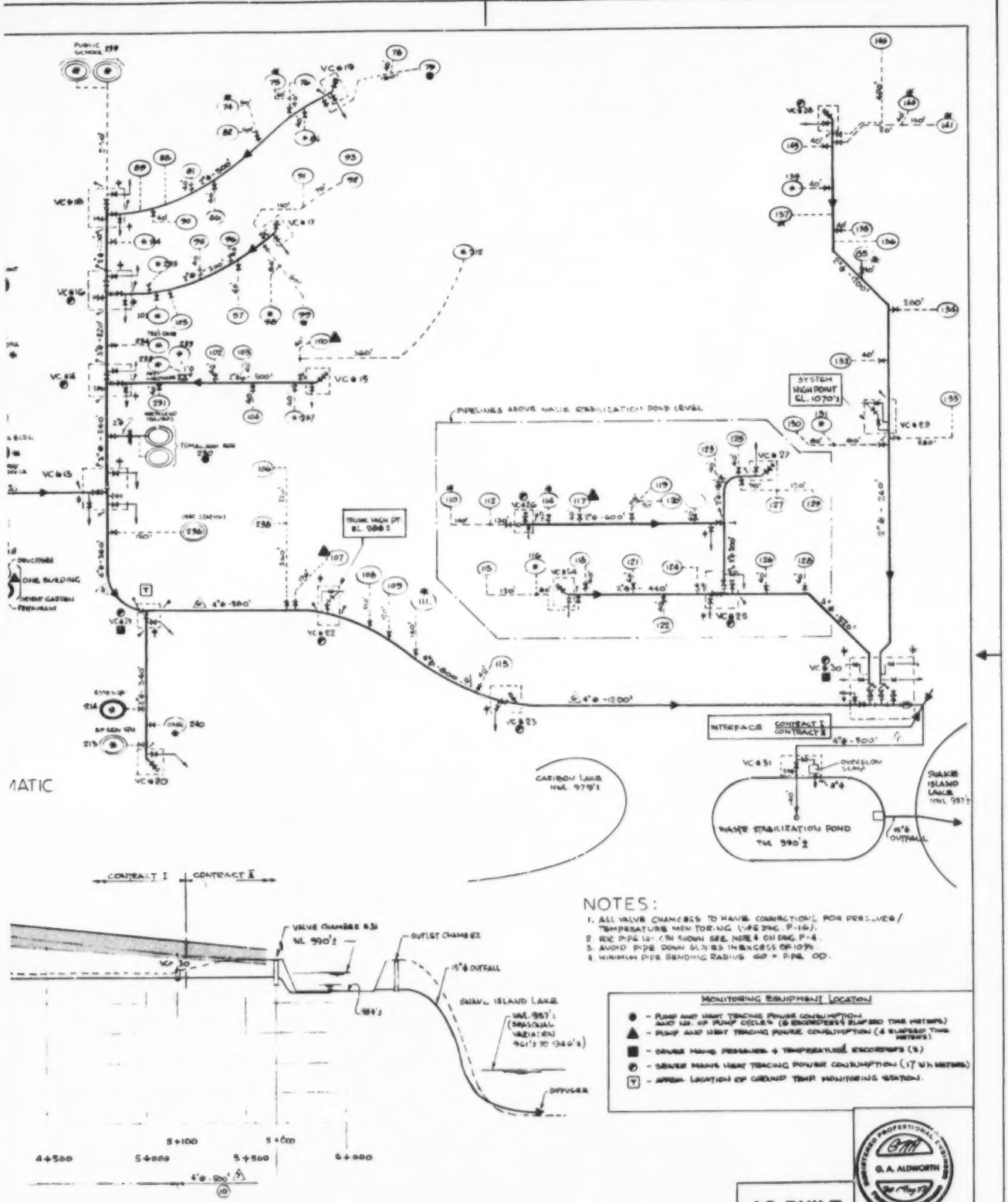
iii) Grinder Pump - Figure 4 shows the bottom of the core and inlet to the pump. The cutter bars which shred the sewage are around the bottom. They are made of hardened chrome steel, and under normal operating conditions should last many years without replacement. The pump impeller is a progressive cavity type.


LEGEND:
BUILDING CONNECTED TO PRESSURE SEWER, 1 PUMP IN 50 IGAL. STORAGE TANK
SAME AS ABOVE; 1 PUMP IN 100 IGAL SPHERICAL TANK
SAME AS ABOVE; 2 PUMPS IN 100 IGAL STORAGE TANK (DUPLEX)
320' APPROX. DISTANCE BETWEEN 2 POINTS ON PIPELINE
PRESSURE SEWER (2" TO 4")
BUILDING BRANCH (1½" Φ)
SHUT-OFF VALVE
DRAIN VALVE - 1" (BURIED OR IN CHAMBER)
FLUSH/CLEAN-OUT/VENT - 2" VALVE
PIPELINE VENT - 1" (BURIED OR IN CHAMBER)
MANUAL AIR RELEASE VALVE
COLD SETTING OF BURIED GRINDER PUMP PACKAGE
VALVE CHAMBER
SEQUENTIAL VENT-UP POINT (SECONDARY FUNCTION TO VENTING OR DRAINING)
PRESSURE SEWER IDENTIFIER (ON TRUNK LINE ONLY)
SYPHON BREAKER VALVE
INDICATES MAX. NUMBER OF PUMPS OPERATING SIMULTANEOUSLY IN THIS PORTION OF PIPELINE
SWING CHECK VALVE WEIGHTED
MAGNETIC FLOW METER
HIGHEST BUILDING IN SYSTEM OR EL. 1030'
PIPELINES ABOVE WASTE STABILIZATION POND LEVEL
LOCAL HIGH POINT OR EL. 975'±
LOWEST BLDG. ON TRUNK LINE OR EL. 970'±
LAKE TEMAGAMI (POSTAGE BAY) NWL. 960'±
PRESSURE SEWER SYSTEM SCHEM
DESIGN GRADIENT RELATIVE TO MAXIMUM WASTE LEVEL IN WASTE STABILIZATION POND
ACTUAL HYDRAULIC GRADIENT BAND
20' FRICTION LOSS
PRESSURE SEWER TRUNK LINE (PR SERIES 100 DR PIPE)
EXISTING GRADE
20' STATIC LIFT
LOWEST BUILDING (97) ON TRUNK LINE, EL. 970'±
FOR PIPELINE VENTS IN VALVE CHAMBERS SEE SCHEMATIC ABOVE
CHAINAGE
SCALE: VERT. 1" = 20'
HORIZ 1" = 500'
PRESSURE SEWER PROFILE & HYDRAULIC GRADIENT

2	LOCATION OF MONITORING EQUIPMENT	Jan 80	RG
1	AS BUILT	JUN '79	
No.	REVISIONS	DATE	APP'D

ONTARIO
MINISTRY OF THE ENVIRONMENT
PROJECT 1-0274-71

FIGURE 1 SCHE



NOTES:

1. ALL VALVE CHAMBERS TO HAVE CONNECTIONS FOR PRESSURE / TEMPERATURE MONITORING (SEE DWG. P-16).
2. ROC PIPE UP / ON SHOWN SEE NOTE 4 ON DWG. P-4.
3. AVOID PIPE DOWN SLOPES IN EXCESS OF 10%.
4. MINIMUM PIPE BENDING RADIUS 60 × PIPE O.D.

MONITORING EQUIPMENT LOCATION

- ● - PUMP AND HEAT TRACING POWER CONSUMPTION AND NO. OF PUMP CYCLES (6 EXPRESS 4 SIMPLEX TIME METERS)
- ▲ - PUMP AND HEAT TRACING POWER CONSUMPTION (4 SIMPLEX TIME METERS)
- ■ - SEWER MAIN PRESSURE & TEMPERATURE EXCEEDANCES (3)
- ◐ - SEWER MAINS HEAT TRACING POWER CONSUMPTION (17 WATTMETERS)
- ▽ - APPROX. LOCATION OF GROUND TEMP. MONITORING STATION.

G. A. ALDWORTH

AS BUILT

MATIC OF PRESSURE SEWER SYSTEM

JAMES F. MacLAREN LIMITED
CONSULTING ENGINEERS, PLANNERS AND SCIENTISTS
WINDSOR · LONDON · WATERLOO · TORONTO

DATE	DRAWN BY	DRAWING No.
APRIL 1977	L M	P-2 of 17
SCALE	CHECKED BY	
AS SHOWN	G.A.A.	

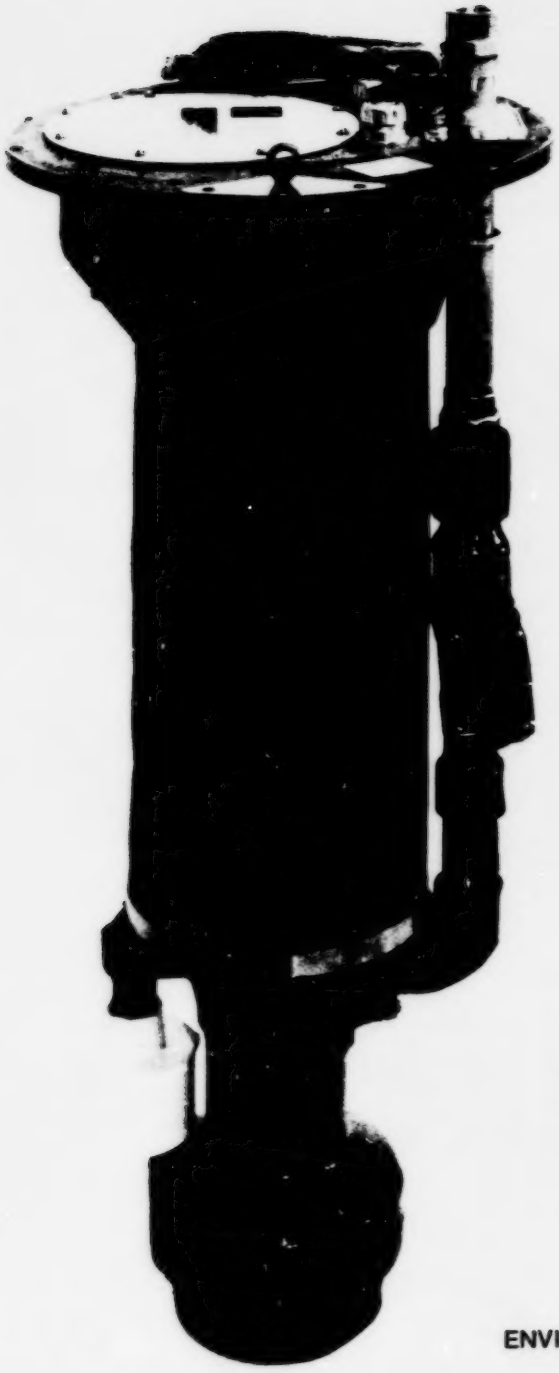
FILE 10817 -D- 9871

ENVIRONMENT | ONE

MODEL FARRELL 210

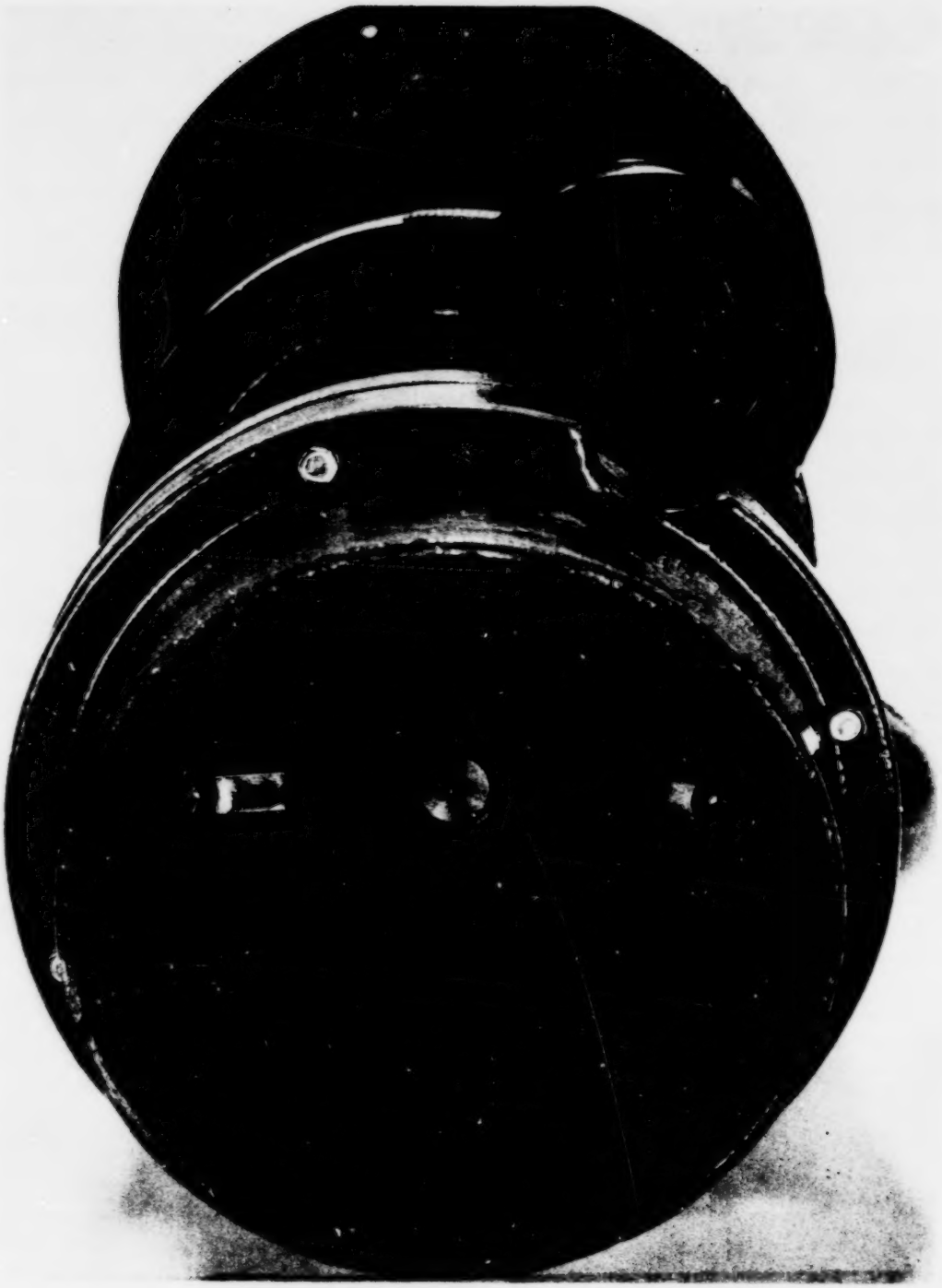
SERIES 1 — GRINDER PUMP

FIGURE 2 GRINDER PUMP



ENVIRONMENT | ONE GRINDER PUMP CORE

FIGURE 3 GRINDER PUMP CORE



ENVIRONMENT | ONE GRINDER PUMP INLET

SHOWING GRINDER

FIGURE 4 GRINDER PUMP INLET

When the core is installed, the tank is completely sealed. There is no possibility of odours from the tank or danger from spillage or overflowing. The holding tank is vented through the building plumbing system. The motor has a separate breather system designed to prevent build up of condensation.

Figure 5 is a pictorial of the inside of the holding tank. Three control levels are shown: ON, OFF and ALARM. Sewage flows into the tank through the inlet pipe at the left. When the ON level is reached, the pump automatically starts. The pump will run until it lowers the level to the OFF position (three or four minutes). For the average home in Temagami, this occurs about five or six times per day.

Although the unit normally starts at the ON position, if for some reason it fails, the tank is capable of storing 225 litres of sewage before the ALARM point is reached. Providing the condition causing failure to the pump is not a power outage, an alarm light will indicate high level. The alarm light should be mounted in a conspicuous location (e.g., next to the telephone).

If solids that are not normally sewerable (small, metallic toys, utensils, etc.) are washed down the drain, the unit may jam and a thermal overload will stop the motor. The motor will attempt to restart a few minutes later and if the object does not clear the motor will again stop. This will repeat until the object is cleared or the level in the tank reaches the upper limit.

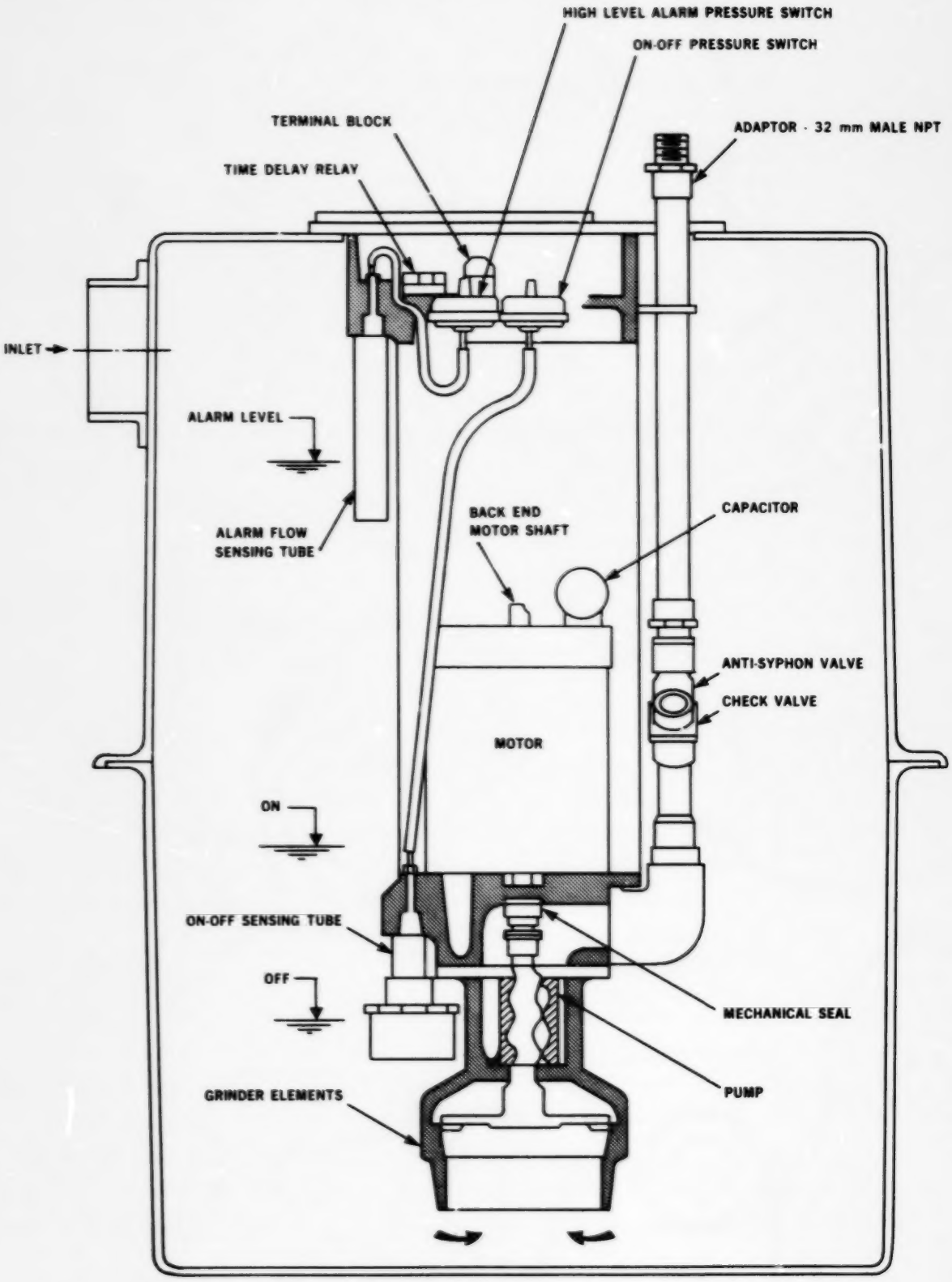


FIGURE 5 GRINDER PUMP PICTORIAL

4 THE MONITORING PROGRAM

4.1 Objectives

The objectives of the monitoring program were to confirm the design criteria and obtain data on operating performance and maintenance requirements to assist in the design of future systems.

4.2 System Operation During Monitoring Period

At the time of preparation of this report, most of the 140 buildings had been connected into the sewer system. In early 1981, a number of homes and business located to the east of valve chamber no. 3 (Figure 1) were acquired by Sherman Mines Limited and sewer service to these homes was terminated.

4.2.1 Sewer System. Since system start up in April 1979, all sewer mains have remained continuously in service. A number of branch lines were found frozen when grinder pumps were initially started. This was due to residual water left from contractor testing. Thawing was accomplished in three to five hours (depending on branch line length) by activating the heat tracing cable.

4.2.2 Grinder Pumps. Between April 1979 and March 1980, 15 grinder pumps had been serviced as shown in Table 1. The pumping units had been in storage on-site in an unused enclosed curling rink, without heat, for 12 to 18 months prior to installation.

The 18% callback rate for service to the 83 pumps installed between November 1979 and April 1980 was considered excessive. A program of pre-installation servicing was instituted by the municipality in March 1980 to inspect and operate each grinder pump at a maintenance facility prior to installation. Callbacks were reduced to only 3 of the next 41 pumps installed. Most malfunctions were likely a result of the long-term storage prior to installation or to rough handling during transport to the site.

4.2.3 Repair and Maintenance. Repair and maintenance are done generally on an as required basis. To date, buried portions of the system have been virtually trouble-free. However, there have been individual grinder pump failures, flooded valve chambers and manholes, and malfunctioning of portions of sewer main heat tracing.

In July 1980, a complete electrical and mechanical inspection of the sewer system was carried out. The findings are presented in Appendix III*. To date the only system modification has been the installation of a small electrical dewatering pump in

TABLE 1 GRINDER PUMP SERVICING RECORD, APRIL 1979 - MARCH 1980

Date	Building Number	Pump Serial Number	Type of Failure	Repairs	Probable Cause of Failure
April 1979	100	14698	Damaged pump stator	Replaced	Unknown
April 1979	15	14666	Poor connection in motor control circuit	Repaired	Damaged during transport, or manufacturer's quality control
Sept. 1979	15	14650	Faulty motor starter	Replaced	Damaged during transport or handling
			Cracked adaptor assembly	Replaced	
July 1979	55	14626	Faulty motor thermal protector	Replaced thermal protector and start timer	Quality control at source
Dec. 1979 and Jan. 1980	29	14604	Damaged anti-syphon valve and pump stator (2)	Replaced valve and stator	Frozen branch line
April 1979	123	14682	Damaged anti-syphon valve	Replaced	Damaged during transport or handling
Oct.1979	227	14612	Loose tie rod	Complete core rebuild	Vibration during transport
Oct. 1979 Nov. 1979	230 230	14555 14561	Damaged pump seals and pump stator	Overhaul	Influent quality (strong detergents, bleaches, etc. used at laundromat)
Mar. 1980	-	14670	Pre-installation inspection	Replaced - Discharge line assembly - Seating rings - Grommets - Gasket - Housing assembly	Damaged during transport

NOTE: Five additional units were serviced.

valve chamber no. 7. Minor repairs (such as replacement of valve insulation) were done at other valve chambers.

4.3 Monitoring

4.3.1 Monitoring Equipment. Monitoring equipment was installed at representative locations to record pressure, temperature, energy consumption and pump cycling throughout the system.

At five of six locations where chart recorders were installed to record grinder pump frequency of operation and branch line pressure, charts were changed only once a month to avoid disturbing the building residents. Data recorded at these five locations was acceptable in view of the relatively few pump cycles per day. At the sixth location (building no. 230) charts were changed weekly. This building is a hotel and laundromat generating large quantities of wastewater with correspondingly high cycling of duplex pumps. Two of the six recorders were inoperative for short periods in December 1979 for unknown reasons. It is suspected that power to the units was shut off.

The operation of the three main line pressure/temperature recorders was considered satisfactory. Some malfunctions occurred but were generally of short duration and did not affect the accuracy of the overall data.

4.3.2 Data Collection. Data were collected daily, weekly or monthly depending on monitoring equipment output. Pressure, temperature and grinder pump cycles were automatically recorded on recording charts. Energy consumption was obtained by reading kWh meters monthly.

The following information was obtained from other sources:

- the magnetic flowmeter at valve chamber no. 30 - sewer flows,
- power outages,
- public sewer maintenance,
- private sewer maintenance,
- general problems, complaints, etc.

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*Appendix III is available from Environment Canada, Environmental Protection Programs Directorate, EPS Publications Section.

4.4 Operating Data

Operating data were gathered for the following system functions:

- public sewer heat tracing energy consumption (kWh meters at 17 locations),
- public sewer temperature and pressure (chart recorders at three locations),
- individual grinder pump energy consumption (kWh meters at 10 locations),
- individual branch line energy consumption (kWh meters at 10 locations),
- individual grinder pump start-stop cycles and operating pressures (chart recorders at six locations),
- soil temperatures at one location.

In addition, daily minimum and maximum ambient temperatures were recorded from January through March 1980 and November 1980 through April 1981.

The public sewer heat tracing energy consumption data are summarized in Table 2. Detailed computation sheets for the data are presented in Appendix I*. The data presented in Table 2 are discussed in Section 6, together with average "time on" of system heat-tracing and operating costs.

Energy consumption data for branch line heat tracing at ten locations is summarized in Table 3. Data for the ten grinder pumps is presented in Section 6 together with operating costs. See Appendix II* for detailed data.

Table 4 presents the results of continuous monitoring at three locations of the public sewer temperature and pressure as monthly data for October 1979 through September 1981. Temperature and pressure scans were also done at eight valve chambers in February 1980, and April and June 1981 to confirm the continuous monitoring data. The results of the scans are presented in Table 5.

Cycling information for six buildings is presented in Table 6. Data is summarized as total cycles over a period and average daily cycles over the entire monitoring period.

Grinder pump operating discharge pressure data for six locations is presented in Table 7.

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* Appendices are available from Environment Canada, Environmental Protection Programs Directorate, EPS Publications Section.

TABLE 2 PUBLIC SEWER MAINS HEAT TRACING ENERGY CONSUMPTION

Number	Traced Pipe Diameter (mm)	Total Tracer Power Rating (kW)	Total Hours on/% Time on							
			Jan. 1980 (14 days)	Feb. 1980 (24 days)	Mar. 1980 (36 days)	Apr. 1980 (28 days)	Jan. 1981 (15 days)	Feb. 1981 (31 days)	Mar. 1981 (32 days)	Apr. 1981 (30 days)
1	50	2.012	310/92	318/55	343/40	795/100	293/81	845/100	890/100	820/100
2	50	2.208	91/27	32/6	97/11	77/11	190/53	181/24	318/41	18/3
3	50,75	3.76	117/35	199/35	220/25	170/25	332/92	122/16	106/13	0/0
4	50	1.728	150/45	174/30	87/10	0/0	41/11	58/8	52/7	12/2
5	50,75	4.126	138/41	160/28	114/13	102/15	514/100	524/70	584/76	126/18
7	75,100	3.788	42/13	26/5	26/3	28/4	45/13	90/12	92/12	34/5
8[a]	50	0.358	-/-	-/-	-/-	-/-	-/-	56/8	28/4	168/23
10	50,75	5.624	78/22	224/39	96/11	43/6	0/0	2/0.27	0/0	4/0.5
14	50,75	3.18	192/62	198/34	167/19	135/20	60/17	72/10	6/1	0/0
16/18	50,75	4.3	33/11	21/4	0/0	9/1	95/26	84/11	88/11	26/4
21	100	2.43	108/35	185/9	272/13	177/26	765/100	580/80	654/85	551/77
22	100	4.52	144/46	111/19	157/18	2/0.3	544/100	562/76	644/84	547/76
23	100	3.496	29/9	9/2	13/2	3/0.5	23/6	14/2	6/1	3/0.4
25	50,75	2.995	50/16	10/2	83/10	154/23	70/19	80/11	57/7	50/7
26	50	2.38	-/0[c]	-/-[c]	441/51	353/53	0/0	0/0	0/0	0/0
28	50	2.8	86/28	54/9	136/16	96/14	46/13	43/6	46/6	25/4
29/30[b]	50,75, 100	7.725	-/-[c]	549/95	549/64	176/26	1455/100	775/100	847/100	816/100

[a] kWh meter inoperative January 1980 - January 1981.
[b] Includes 350-watt enclosure heater assumed to operate 18 h/d during cold season.
[c] Readings faulty.

TABLE 3 PRIVATE SEWER LINES HEAT TRACING ENERGY CONSUMPTION

Building Number	Service Line Length (m)	Total Tracer Power Rating (kW)	Average Time on (h/d)											
			Feb. 1980 (23 days)	Mar. 1980 (30 days)	Apr. 1980 (24 days)	May 1980 (29 days)	Oct. 1980 (27 days)	Nov. 1980 (43 days)	Dec. 1980 Jan. 1981 (27 days)	Jan. 1981 (28 days)	Feb. 1981 (32 days)	Mar. 1981 (30 days)	Apr. 1981 (29 days)	May 1981 (29 days)
18	18.3	0.115	4.7	1.9	1.6	0.5	0	0	0.17	0.24	1.4	1.4	1	0
55	22.2	0.140	8.8	1.1	2.9	0.2	0.14	18.9	0	0	0	0	0	0
79	51.5	0.324	10.8	9.6	7.1	1.2	0.6	3	1.4	8.3	7.8	10.6	11.4	1.8
100	7.6	0.048	24	23.2	23.7	0*	0	0	0	0	0	0	0	0
107	65.8	0.415	8.9	7.9	7.3	0.3	0.25	1.2	4.3	5.1	7.8	3.4	1.4	0.07
117	27.4	0.174	0	0	0	0	0	0.2	0.02	0	0.19	0	0	0
201	2.4	0.015	0	0	0	0	0	0	0	0	0	0	0	0
218	15.2	0.096	24	20.7	24	-**	0	0	0	0	0	0	0	0
228	20.4	0.129	3	2.1	0.8	0.04	0	0.03	1.4	1.7	1	1	0.02	0
230	7.3	0.046	6	4.6	1.7	1	0	2.6	10.9	5.7	2.2	1	0.25	0.09

* Heating trace circuit turned off
** Thermostat malfunction

Notes

1) Tracer rating = 6.3 W/m
2) Service line ∅ = 37 mm

TABLE 4 SEWAGE TEMPERATURES AND SEWER MAIN PRESSURES

Date	Temperatures (°C)			Pressures (kPa)*		
	Valve Chamber 5	Valve Chamber 21	Valve Chamber 30	Valve Chamber 5	Valve Chamber 21	Valve Chamber 30
October 1979	10 - 15	-	-	35 - 100	-	-
November	7 - 10	-	-	45 - 90	-	-
December	4 - 7	-	-	50 - 100	-	-
January 1980	4 - 9	-	-	50 - 105	-	-
February	5 - 9	-	-	49 - 110	-	-
March	6 - 9	-	-	55 - 110	-	-
April	-	5 - 11	-	-	48 - 53	-
May	-	10 - 18	-	-	48 - 76	-
June	-	11 - 17	-	-	48 - 76	-
July	18 - 21	17 - 20	18 - 19	97 - 138	48 - 76	21 - 35
August	18 - 21	17 - 21	12 - 20	97 - 131	48 - 76	21 - 35
September	12 - 22	10 - 21	12 - 19	90 - 124	41 - 70	21 - 35
October	10 - 13	8 - 11	8 - 12	90 - 117	41 - 76	21 - 35
November	6 - 9	7 - 8	5 - 8	83 - 110	41 - 62	21 - 35
December	4 - 7	4 - 7	3 - 5	80 - 124	35 - 62	21 - 28
January 1981	4 - 15	4 - 10	3 - 5	83 - 110	41 - 70	14 - 28
February	11 - 15	9 - 11	4 - 9	90 - 131	41 - 70	14 - 35
March	10 - 15	10 - 11	5 - 8	83 - 124	48 - 76	14 - 35
April	13	10 - 14	9 - 12	144 - 190	83 - 124	20 - 41
May	13 - 16	13 - 18	12 - 16	138 - 203	83 - 124	20 - 48
June	14 - 18	16 - 20	15 - 18	138 - 241	83 - 124	20 - 41
July	16 - 23	18 - 24	16 - 22	138 - 210	69 - 138	20 - 41
August	16 - 23	20 - 23	20 - 22	152 - 224	83 - 138	20 - 41
September	16 - 23	20 - 22	20 - 23	138 - 224	83 - 138	20 - 41

* System static head = approximately 30.4 kPa.

TABLE 5 PRESSURE SEWER TEMPERATURE AND PRESSURE MEASUREMENTS AT VALVE CHAMBERS

Chamber Number	Line Temp (°C)	Line Pressure (kPa)	Remarks
2	6-8	62-69	-
3	6-7	83	Chamber flooded
5	15-16	90-97	15 cm water in chamber
10	9-10	69-76	Chamber flooded
12	10	47-55	Chamber flooded
18	8-10	55	Some water in chamber
19	-	-	No gauge connections
21	6-8	52-83	
29	-	-	No gauge connections
30	12-15	14	Some water in chamber

Scans carried out: 12 & 13 February, 1980
15 & 16 April, 1981
23 & 24 June, 1981

TABLE 6 GRINDER PUMP CYCLE FREQUENCY

Number	Oct. 1979-Mar. 1980 (182 days)	Apr. 1980-Mar. 1981 (365 days)	Apr. 1981-Sept. 1981 (183 days)	Average Cycles Per Day (Oct. 1979-Sept.1981)
18 House	1262	2880	1846	8
55 House	4606	6620	2892 (150 days)	20 *
79 House	1027	2413	2251	8
201 MNR	726 (60 days)	5585	3309	16**
228 Restaurant	544 (60 days)	6050	4584	18
230 Hotel/ Laundromat	2456 (60 days)	18230	9317 (145 days)	49

* leak in building plumbing at this house
** continuous running fixture in this building

TABLE 7 TYPICAL PRESSURE AT GRINDER PUMP DISCHARGE

Building Number	Typical System Pressure (Pump Off) (kPa)	Pressure at Pump Start-up (kPa)	Typical Operating Pressure (Pump On) (kPa)
	1 Oct. 79 - 31 Mar. 80 (12-78 houses on line)		
18*	69 - 90	173 - 262	104 - 138
55	41 - 62	117 - 186	69 - 90
79	14 - 28	62 - 90	28 - 55
201	83 - 97	104 - 138	104 - 117
228	41 - 69	138 - 173	62 - 90
230	69 - 83	104 - 145	83 - 104
	1 Apr. 80 - 31 Mar. 81 (78-114 houses on line)		
18*	62 - 90	97 - 131	69 - 104
55	21 - 48	138 - 173	35 - 76
79	14 - 28	62 - 90	28 - 55
201	69 - 83	117 - 138	97 - 117
228	41 - 69	138 - 173	62 - 90
230	48 - 83	104 - 138	69 - 90
	1 Apr. 81 - 30 Sept. 81 (114-140 houses on line)		
18*	55 - 69	124 - 166	76 - 97
55	62 - 83	97 - 124	69 - 90
79	14 - 35	69 - 104	28 - 48
201	55 - 69	138 - 173	62 - 90
228	48 - 69	173 - 207	76 - 97
230	62 - 83	207 - 242	69 - 104

* Lowest building on trunk line.

Daily minimum and maximum ambient temperatures are presented in Table 8. During January 1980 and January 1981, the minimum daily ambient air temperature approached the lowest design temperature of -40°C.

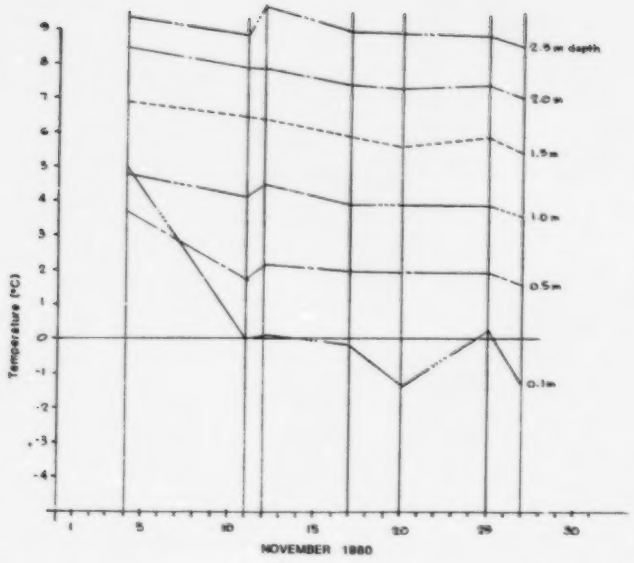
A soil temperature monitoring station was installed near valve chamber no. 21 with thermocouples located at various depths down to 2.5 m. Periodic readings were taken from November 1980 through April 1981. Results are presented in Figure 6.

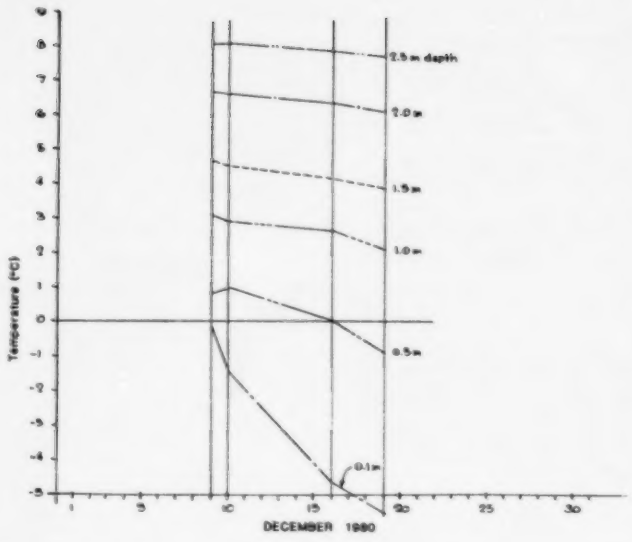
Data on daily sewage flow to the waste stabilization pond were obtained from the magnetic flow meter/recorder located at valve chamber no. 30 and are presented in Table 9. The accuracy of data gathered prior to November 1980 should be considered questionable because of recorder operating problems.

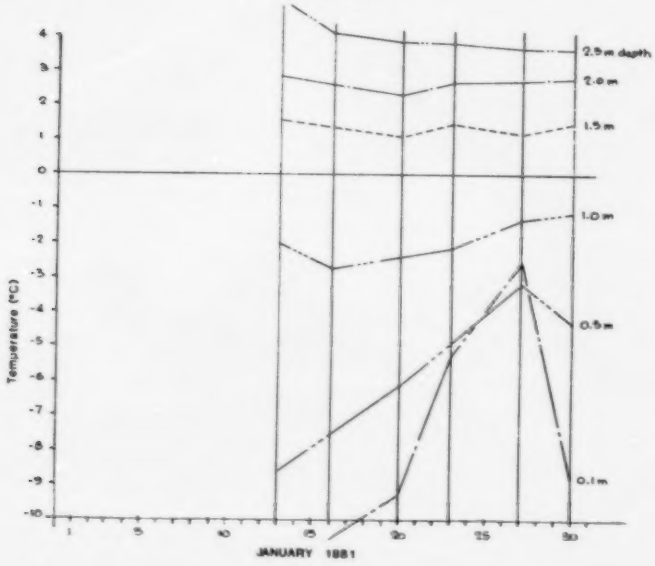
TABLE 8 AMBIENT TEMPERATURES(°C)* AND FREEZING DEGREE DAYS (FDD)

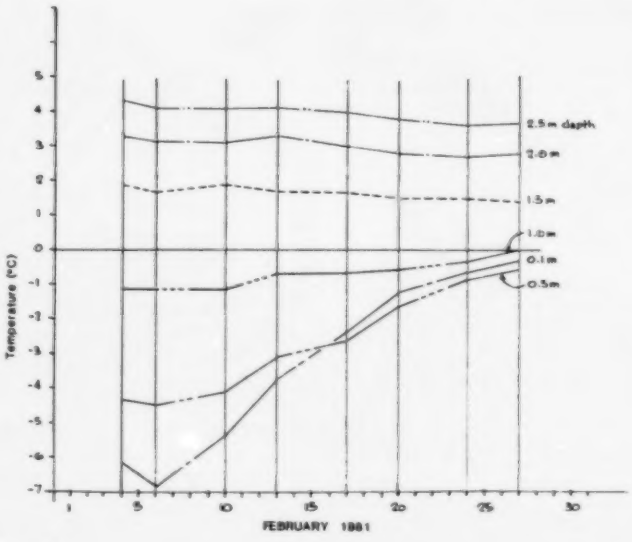
	January 1980			February 1980			March 1980			November 1980			December 1980			January 1981			February 1981			March 1981			April 1981		
Date	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD	Min.	Max.	FDD
1	-14	- 1	7.5	-24	-14	19	-30	0	15				- 5	5	0										- 1	15	-7
2	-14	- 1	7.5	-27	-14	20.5	-30	0	15				-13	- 3	8							-11	0	5.5	- 3	10	-3.5
3	-20	-12	16	-27	-14	20.5	-31	3	14	- 2	12	-5	-24	- 8	16				-32	-17	24.5	-19	- 3	11	- 3	19	-8
4	-29	-11	20	-27	-14	20.5	- 8	5	1.5	0	11	-5.5	-26	- 6	16				-31	-16	24.5	-21	- 4	12.5			
5	-22	-18	20	-24	-12	18	-12	2	5	- 6	0	3	-23	- 3	13	-39	-10	24.5	-33	- 6	19.5	-13	- 1	7			
6	-22	-18	20	-26	-11	18.5	-24	2	11	- 4	3	0.5				-20	- 3	11.5	-13	- 1	7	-15	- 4	9.5	- 9	9	0
7	-22	-18	20	-26	- 7	14.5	-23	5	9	- 6	1	2.5				-22	-18	20							- 8	13	-2.5
8	-22	-18	20	-24	- 6	15	-20	5	7.5				-18	- 6	12	-29	-14	21.5							1	12	-7
9	-27	-12	19.5	-24	- 2	13	-20	5	7.5				-13	- 5	9	-23	- 6	14.5	-20	- 5	12.5	- 3	7	- 2	0	14	-7
10	-24	- 7	16.5	-24	- 2	13	-21	5	8	- 7	- 3	5	-15	- 8	11.5				-20	- 5	12.5	- 7	- 1	4	- 6	10	-2
11	- 9	4	2.5	-24	- 2	13	-14	- 3	8.5	- 5	- 2	3.5	-31	-12	20.5				- 9	4	2.5	-16	5	5.5			
12	-23	- 7	15	-22	- 1	11.5	-24	0	12	- 7	- 1	4	-28	- 8	18	-30	- 9	19.5	-26	-11	18.5	- 9	3	3			
13	-23	- 7	15	-19	- 1	10	-25	0	12.5	- 3	0	1.5				-22	- 8	15	-24	- 5	14.5	-10	2	4	- 6	17	-5.5
14	-23	- 7	15	-17	- 0	8.5	-11	0	3	- 6	0	3				-22	- 5	13.5							- 5	3	1
15	-24	- 6	15	-24	1	11	-15	5	5				-20	-11	15.5	-15	- 1	8							-16	- 1	8.5
16	- 7	- 1	4	-30	- 7	18.5	-15	5	5				-29	- 7	18	-23	- 4	13.5	-14	10	2	-28	- 1	14.5	- 5	17	-6
17	- 6	2	2	-30	- 7	18.5	-22	7	7.5	- 8	- 1	4.5	-35	- 3	19				2	5	- 3.5	-22	- 4	13			
18	- 5	4	0.5	-30	- 7	18.5	-10	6	2	-14	- 3	8.5	-23	-10	16.5				4	11	- 7.5	-27	- 1	14			
19	-19	- 5	12	-19	0	9.5	-21	9	6.5	-11	0	5.6	-27	- 5	16	-23	- 1	12	2	9	- 5	-14	7	3.5			
20	-19	- 5	12	-14	3	5.5	-21	13	4	0	3	-1.5				-20	2	9	2	7	- 4.5	- 4	10	- 3	-12	2	5
21	-19	- 5	12	-18	-12	15	- 3	6	- 1.5	- 2	1	0.5				-22	- 2	12							-14	6	4
22	-19	- 5	12	-24	- 7	16.5	- 5	5	0	- 7	2	2.5	-33	- 5	19	- 7	2	2.5							- 8	12	-2
23	-27	-17	22	-22	- 1	11.5	- 5	5	0				-10	- 1	5.5	-12	- 1	6.5	- 7	7	0	- 8	11	- 1.5	- 1	2	-0.5
24	-27	-19	23	-22	- 1	11.5	-10	3	3.5				-23						- 3	5	- 1	- 4	12	- 4	- 3	4	-0.5
25	-30	-17	23.5	-22	- 1	11.5	- 8	5	1.5	-11	- 4	7.5							- 4	4	0	-11	14	- 1.5			
26	-24	- 6	15	-39	-14	26.5	- 6	8	- 1	- 9	0	4.5				-19	-	7.5	- 9	- 2	5.5	-11	12	- 0.5			
27	-24	- 6	15	-16	-11	13.5	- 5	6	- 0.5	- 5	- 3	4				-22	- 7	14.5	-14	12	1	- 7	10	- 1.5	- 5	17	-6
28	-24	- 6	15	-33	-18	25.5	- 4	6	- 1	- 5	- 1	3				-26	- 5	15.5							- 4	17	-6.5
29	-26	-17	21.5	-33	-18	25.5	- 8	8	0							-25	- 6	15.5							0	16	-8
30	-29	-16	22.5				- 8	8	0							-28	- 6	13.5				-10	8	1	- 5	11	-3
31	-27	-14	20.5				-12	13	- 0.5													- 2	12	- 5			

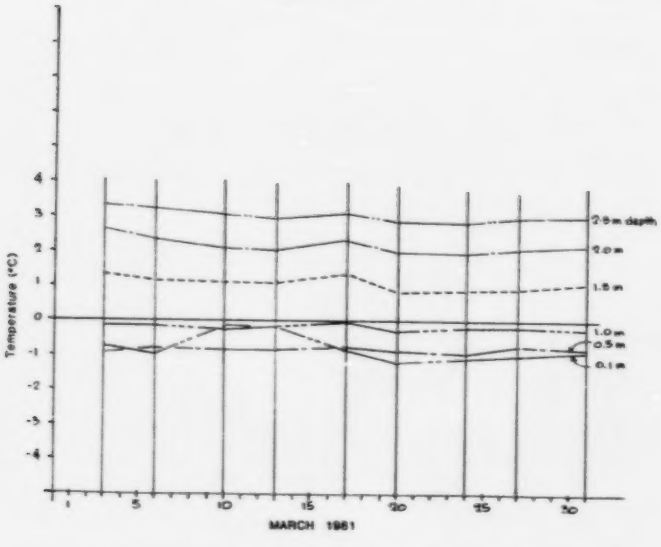
* Obtained from min/max thermometer located at Temagami Electric (thermometer read at 0800-0990 h and 1600-1800 h).











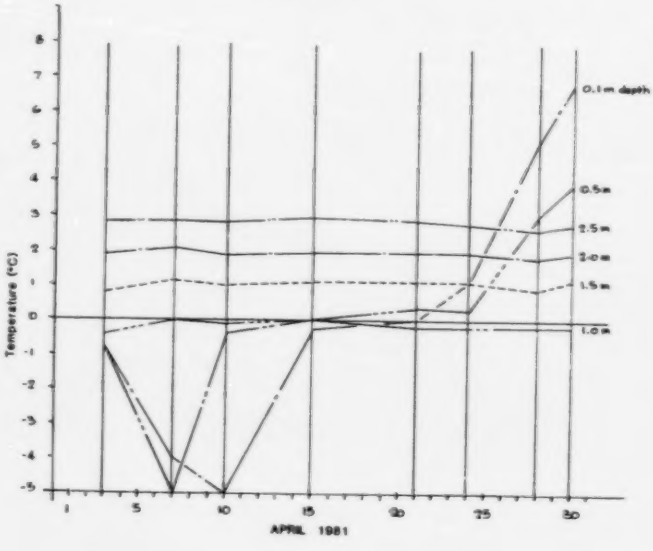


FIGURE 6 SOIL TEMPERATURES

TABLE 9 AVERAGE DAILY SEWAGE FLOW

	Average Daily Flow (L)	Number of Buildings On-Line	Average Lpd per Building
October 1979**	41 369	20	2 068
November**	38 641	30	1 288
December**	38 868	47	827
January 1980**	35 459	51	695
February**	37 277	60	621
March**	25 617	78	328
April**	14 729	85	173
May**	9 597	89	108
June**	7 101	90	79
July*	-	98	-
August*	-	100	-
September*	-	102	-
October*	-	102	-
November*	-	105	-
December	44 142	105	420
January 1981	29 922	105	285
February	29 149	110	265
March	33 022	114	290
April	58 948	117	504
May	46 046	118	390
June	67 131	120	559
July	66 285	125	530
August	75 377	133	567
September	75 918	140	542

* flow meter inoperative July - November 1980.
** meter calibration questionable.

4.5 Analysis of Data

No major malfunctions have occurred in the system. A number of valve chambers were not water tight and sewer main heat tracing malfunctioned at four locations. However, these deficiencies did not adversely affect overall system performance.

4.5.1 Public Sewer Heat Tracing. A review of the detailed data indicated consistent variations in energy consumption readings from month to month. This confirms the reliability of the data.

At electrical meters no. 1, 5, 21, 22 and 29/30, some readings indicated consumption greater than the power draw required for continuous operation. At meter no. 1 it is probable that the installed length of heat tracing cable is greater than that shown. Readings at meters no. 5, 21, 22, and 29/30 between January 15 and 30, 1981 were disregarded. All readings at meter no. 29/30 were consistently greater than 100% due to the power required to heat the meter chamber itself. The monthly average "on time" for the entire system was assumed for these locations.

At the six locations where energy consumption was highest ("on time" generally greater than 60%), there is a long sewer upstream of the monitoring point with no branch lines. The high resulting heat loss increases the energy requirement.

A number of failures occurred in the electrical trace wire. It is suspected that water entered the cable through spliced joints.

Monitoring during cold weather showed that the heat tracing maintained temperatures in the mains several degrees above freezing, providing on adequate reserve of heat to sustain a temporary power failure.

4.5.2 Public Sewer Temperature and Pressure. Readings taken at eight locations in February 1980, April 1981 and June 1981, confirmed the reliability of data obtained at the three recording stations (V.C. 5, 21 and 30). Sewage temperatures varied from 6 to 10°C and line pressures varied from 14 to 97 kPa (see Table 5).

4.5.3 Service Lines. Heat tracing on four of the service lines monitored did not operate at any time (buildings 100, 117, 201 and 218, Table 3). The thermostats and circuits were checked for malfunction and were found faulty only at two locations (buildings 100 and 218). Operating durations for the other six locations were consistent from month to month (see Tables 3, 11 and 12), confirming the reliability of the data.

4.5.4 Grinder Pumps. Simultaneous pump operation was close to design expectations (i.e., 10 at once). Recorded pump cycles for the residential buildings varied from 8 to 18 cycles per day per building. Cycles at building 230 (hotel and laundromat) were high (49 cycles/day average). The high cycling frequency along with the harsh nature of the wastewater caused several breakdowns in this particular pump.

Although an interior location is preferred for grinder pumps for physical protection and ease of maintenance, the exterior installations (approximately 30%) operated reliably. Grinder pump energy consumption includes an integral continuously operating resistance heater (20 watts). Totai energy consumption was less than expected based on the number of pump cycles recorded.

4.5.5 Soil Temperatures. A review of the data indicated that maximum frost penetration is approximately 1.2 metres in the vicinity of the sewer; temperatures below that depth remain constant during the winter.

4.5.6 Sewage Flows. Daily sewage flow data recorded from April to June 1980 appear to be unreasonably low and were disregarded. In late June 1980 the flow recorder was damaged by lightning. Repair and calibration were completed in November 1980. Sewage flows were then checked manually using a 200-litre drum at the discharge into the lagoon. Readings from December 1980 onwards are considered to be accurate. Daily sewage flows were found to be well below the 267 000 L/d capacity (76 000 L/d in September 1981). However, adequate scouring is being provided and no clogging or scum build up has occurred. Syphon breakers at two high points, required to introduce air to prevent creation of a vacuum behind a slug of water flowing downhill, were found to function properly.

5 SYSTEM DESIGN, CONSTRUCTION AND OPERATION RECOMMENDATIONS

5.1 Design and Construction

Construction began in August, 1977 and was completed in August, 1978. Difficulties encountered are outlined below. These should be carefully investigated in the future design and construction of similar systems.

A. Pipe Joints

Heat trace cable raceways should be kept aligned at all joints. Laying the pipe on a curved alignment will cause rotation of the pipe and its integral raceway. This is acceptable as long as the raceway is kept in the lower 180° of the pipe segment to prevent overheating of the pipe should air become trapped in it.

Where couplings are used to join small diameter pipe, half-shell insulators should allow for the increased outside diameter while still providing the specified insulation thickness.

B. Branch Connections

Compression fittings should be installed with a stainless retainer ring in order to prevent failure from thermal contraction. If insulation is foamed in place it should be confirmed that the foam will not have the potential of causing local cable burnout. The need for shut-off valves on branch lines should be reviewed.

Service saddles for branch connections may have a rubber O ring to effect the seal. Once the connection is made the ring may become permanently deformed and therefore not suitable for re-use. Therefore, a new O ring should be installed whenever assemblies are taken apart and reinstalled.

C. Electrical Codes

The local hydro authority may require the use of a seal tight conduit for heat trace cable within valve chambers. The authority may also not permit the underground splicing of heat trace cable; therefore, accurate dimensional take off and ordering is necessary. Discussions should be held with the local hydro authority at the design stage to avoid delays and extra costs later.

D. Pipe Wrapping

Although heat-shrink sleeves are satisfactory for waterproofing insulation at pipe joints on straight pipe runs, a more flexible wrapping material is appropriate at

complex assemblies such as branch tees. The material used at Temagami was "Tapecoat 20", an asphalt impregnated wrapping used extensively in the gas pipeline industry.

E. Control Thermostats

Gas capillary thermostats are linked to the point being sensed by 3 to 6 m capillary tubes. It may therefore not be possible to install these thermostats where the sensing point is in the middle of the roadway. Proper thermostat calibration should be established before installation and thermostat operation should be checked after installation to verify that the capillary tube has not been damaged.

F. Grinder Pumps

A detailed survey should be done to determine whether grinder pumps can in fact be installed in building interiors. Where exterior installations are required, it may be preferable to use a completely prefabricated outdoor manhole unit for the grinder pump and holding tank assembly to avoid the ground or surface water leakage that can occur in a site-built manhole. The manhole should be located very close to the building so that the control thermostat and the grinder pump junction box can be placed inside.

G. Bedding and Backfilling

To avoid puncture of the outer skin over the insulation on the piping in blasted rock trenches, protective sandbagging should be used to prevent the pipe from moving during installation. Also careful inspection of pipe bedding and backfilling is required to ensure that no prohibited material is used.

H. Valve Chambers

Future designs should minimize the number of valve chambers and ensure that they are water tight since they could very well represent the major maintenance item in the system (i.e., potential for flooding).

I. Property Lines

The major advantage of the flexible polyethylene pipe pressure sewer system is that it can be laid wherever soil conditions are favorable without regard to formal property lines. However, some property owners may refuse to allow lines on their property. All property lines must be well defined before construction commences to avoid the inadvertent location of the pipeline on private property against the wish of the owner. A method of accurately determining the location of the pipe anywhere must be

implemented. In a heat tracing system it is possible to energize the cable and use a magnetic detector to find the line. In a non-heat trace system surface markers may be required.

J. Electric Power Supply

Grinder pump units normally require 240 volt power. Some buildings may only have 120 volt service. A survey should be made of all buildings at the design stage to determine existing electrical service and inform the owner of any required changes.

5.2 Operation and Maintenance

Since commissioning in March 1979 the sewer system has remained in continuous service, without major malfunction. Leakage in the system was virtually non-existant, and heat loss and resulting energy requirements were minimal, indicating good insulation performance. The following recommendations can be made.

A. Grinder Pumps

A small pump testing/repair facility is required for pump maintenance and repair, and to pre-service and operate grinder pumps prior to installation. Storage of the pumps should be no more than two months.

B. System Inspection

Periodic inspection of the sewer system should be carried out with particular attention given to:

- operation of heat tracing circuits and controls. Electrical circuits should always be turned off before personnel enter a valve chamber.
- sealing of heating cable at raceway exits. Recent improvements in heating cable sheathing may provide better protection against water damage.
- inspection of valve chambers for valve operation, insulation condition, and water tightness.
- monitoring of system temperatures and pressures on a regular basis during cold weather for early warning of potential problems such as clogging, faulty heat tracing, etc.

C. Thermostats

As the mechanical thermostats were found to be inaccurate, electronic thermostats should be considered in the future.

6 SYSTEM COSTS

6.1 Capital Costs

The low tender of $917 000 submitted in July, 1977, by Raken Construction Ltd. covered all elements of the pressure sewer system, including supply and installation of 4500 metres of sewer mains and 1800 metres of service lines to buildings, heat tracing, electrical controls, valves and chambers, grinder pump manholes, pipe fittings, branch connections, etc., and was accepted. The supply and installation of grinder pump units was not included. Estimated 1978 costs for these units were as follows:

SUPPLY:

Unit Type	Number	Unit Cost	Total Cost
Single pump - 225 litre tank	124	$ 1 300	$ 161 200
Single pump - 450 litre tank	20	1 500	30 000
Duplex pump - 450 litre tank	6	2 200	13 200
			$ 204 400

INSTALLATION including:

- setting up the pump and tank package,
- connecting pump package to house facilities and to the branch connection brought to the house wall,
- all electric wiring and connection to the pump and the branch heat tracing,
- freeze protection for unit, if required,
- modifications to hydro service, if required.

Unit Type	Number	Unit Cost	Total Cost
Single pump	144	$ 800	$ 115 200
Duplex pump	6	1 200	7 200
			$ 122 400

During construction, the extent and location of rock above and near the ground surface confirmed the earlier estimate that the cost for installation of a gravity sewer system would have been in the order of two times the cost of the pressure sewer system.

6.2 Operation and Maintenance Costs

Operating costs are presented in Tables 10, 11 and 12 for the following:

- public sewers heat tracing electrical power costs;
- private branch line heat tracing electrical power costs (ten representative locations); and
- grinder pump electrical power costs (ten representative locations).

TABLE 10 PUBLIC SEWER HEAT TRACING OPERATING COSTS

Period	Total kWh Consumed	Estimated Cost ($)*	Estimated Cost/day ($)
Jan. 1980 (15 days)	6 242	467.24	34.63
Feb. (24 days)	6 926	453.02	18.87
Mar. (36 days)	6 940	480.58	13.35
Apr. (29 days)	6 930	442.46	15.26
Dec. 80 - Jan. 81 (59 days)	21 200	944.80	16.99
Feb. (28 days)	16 130	786.74	28.10
Mar. (32 days)	17 130	799.20	24.22
Apr. (30 days)	12 890	593.28	19.78

Total cost for heating season (3 Dec. 1980 - 30 Apr. 1981) = $3 124.02 ($20.97/day)

* Based on power cost of 10.6¢/kWh for first 250 kWh and 3.56¢/kWh for remainder at each meter.

6.2.1 Public Sewer Heat Tracing Costs. The number of buildings on line in January and March 1980 was 51 and 84, respectively. During the first cold weather period monitored (January - March 1980), energy consumption averaged 261 kWh/d or approximately 73% of original estimates. Actual energy costs for this period averaged $18.93/day, compared to $12.50/day estimated. The higher-than-estimated cost for operation of the public sewer heat tracing was attributable to the rate structure of Ontario Hydro. For the first 250 kWh consumed each month at each of the 17 meter locations, a charge of 10.6 cents/kWh was made.

TABLE 11 PRIVATE SEWER HEAT TRACING OPERATING COSTS

Building Number	Service Line Length (m)	Total Tracer Power Rating (kWh)	Total Operating Hours	Total Energy Consumption (kWh)	Total Cost* $	Average Cost Per Day $
(1 January - 28 April 1980: 119 days)						
18	18.3	0.120	223.2	27	0.96	0.008
55	22.2	0.146	343.1	50	1.78	0.015
79	51.5	0.338	892.6	302	10.75	0.09
100	7.6	0.050	2053.3	103	3.67	0.03
107	65.8	0.432	652.7	282	10.04	0.084
117	27.4	0.180	0.1	0	0	0
201	2.4	0.016	0.1	0	0	0
218	15.2	0.100	2272.2	227	8.08	0.068
228	20.4	0.134	175.0	23	0.82	0.007
230	7.3	0.048	312.9	15	0.53	0.004
(28 April 1980 - 30 April 1981: 367 days)						
18	18.3	0.120	143.3	17	0.61	0.002
55	22.2	0.146	518.2	76	2.71	0.007
79	51.5	0.338	729	247	8.79	0.024
100	7.6	0.050	0	0	0	0
107	65.8	0.432	742	321	11.43	0.031
117	27.4	0.180	10.2	2	0.07	0
201	2.4	0.016	0	0	0	0
218	15.2	0.100	381	38	1.35	0.004
228	20.4	0.134	165.2	22	0.78	0.002
230	7.3	0.048	864.6	42	1.50	0.004

* Based on power cost of 3.56¢/kWh.

The number of buildings on line during December 1980 and April 1981 was 105 and 117, respectively. Energy consumption for this second cold weather period (December 1980 - April 1981) was found to average 455 kWh/d or approximately 121% of original estimates. The total energy consumption during the cold weather season of 1980-1981 was about 67 000 kWh versus the seasonal estimate of 72 000 kWh. Again, the high daily energy cost ($21.11 actual versus $12.50/day estimated) was attributable to the higher cost for the initial 250 kWh of energy consumption at each meter.

TABLE 12 GRINDER PUMP OPERATING COSTS
(February 1980 - September 1981: 597 days)

Building Number	Total Energy Consumption (kWh)	Total Operating Cost ($)*	Average Operating Cost/Pump/Day ($)	Typical Annual Operating Cost/Pump ($)
18	84	2.99	0.005	1.83
55	304	10.82	0.019 (565 days)	6.94
79	221	7.87	0.013	4.75
100	283	10.07	0.023 (444 days)	8.40
107	248	8.83	0.015	5.48
117	219	7.80	0.013	4.75
201	274	9.75	0.016	5.84
218**	386	13.74	0.023	8.40
228**	274	9.75	0.016	5.84
230**	1380	49.13	0.082	29.94

* Based on energy cost of 3.56/kWh. Includes power consumption of pump core resistance heater (20 W) operating continuously.
** Dual pumps installed at these locations; costs shown are for one pump only.

6.2.2 House Connections Heat Tracing Costs. Annual operating costs ranged between 0 and 125% of original estimates with the average cost being $2.72 per year or 30% of the design estimate. A summary of the ten branch line heat tracing operating costs is presented in Table 11.

6.2.3 Grinder Pump Operating Costs. Operating costs for grinder pumps at all but one (hotel-laundromat) of the monitored locations were close to original estimates (i.e., 1.5 cents/day) over one year. A summary of operating costs is presented in Table 12.

6.2.4 Repair and Maintenance Costs. Maintenance and emergency repairs are carried out on an as required basis by a local employee of the Ontario Ministry of the Environment Operations Division, with some assistance from town employees.

As previously noted, a comprehensive mechanical and electrical inspection was carried out in July 1980 to identify system repair and/or upgrading requirements. A budget of $2500 was provided by MOE Operations, Sudbury, to do some of the repairs and to install a dewatering pump in valve chamber no. 7.

Costs for repairing individual grinder pumps are covered by a fund set up by the Town of Temagami based on a monthly charge of $5.00 per building. As discussed in Section 4.2.2, 18 grinder pumps were repaired between April 1979 and July 1981. Typical

material costs for service and repair to a grinder pump varied from $50 for replacement of the stator (rubber boot) to approximately $1 000 for a major repair (i.e., complete overhaul of the pump core).

6.2.5 Summary. While actual energy consumption on the public portion of the sewer system was less than estimated, the cost for energy was greater due to the unanticipated rate structure used by the local hydro authority. As discussed in Sections 6.2.3 and 6.2.4, operating costs for the private portions of the system were found to be close to the original estimate.

Maintenance costs for the private portions of the sewer system were related to repair and eventual replacement of grinder pumps. The estimated cost for maintenance and replacement (25-year life cycle) for a grinder pump was $110 per year. Up to October 28, 1981, with 138 grinder pumps installed, 23 units had required service or repair. As previously discussed, pump malfunctions were significantly reduced after the implementation of a pre-servicing program in March 1980. During the period from April 1980 through September 1981, 52 pre-serviced units were installed and eight service calls were made for minor repairs, such as stator replacement or small control element replacement. The Town of Temagami presently assesses each user $60 per pump/year to maintain a fund to partially cover the cost of service and repair to the grinder pumps.

Annual operating and maintenance costs for the public and private portions of the pressure sewer system are summarized as follows:

SERVICES (electricity)	- public sewers heat tracing	$3 124 (1980-81)
	- branch line heat tracing	$ 0 - $11/bldg.
	- grinder pump (residential)	$ 2 - $ 8/pump
	(other)	$ 6 - $30/pump
MATERIALS	- minor/major repairs (system)	$1 000 +
	- grinder pumps	$ 60/pump
LABOUR	- operation (1/2 person-day/week) @ $20/hour	$4 160
	- maintenance (1 person-day/week) @ $20/hour	$8 320